4. VULNERABLE GROUNDWATER AREAS

One of the crucial tasks to protect our drinking water sources includes the identification of vulnerable areas needing protection from possible threats. This is accomplished through mapping water source vulnerability. Niagara Peninsula Source Protection Area (NPSP Area) groundwater vulnerability studies focus on two areas to be protected: Highly Vulnerable Aquifers (HVAs) and Significant Groundwater Recharge Area's (SGRAs).

4.1 Highly Vulnerable Aquifers (HVA)

HVAs for the NPSP Area were delineated (NPCA, 2009a) based largely upon earlier vulnerability mapping completed as part of the NPCA Groundwater Study (WHI, 2005). This earlier mapping combined two vulnerability assessment methods listed in the Assessment Report Technical Rules (TR) (MOE, 2009): (i) intrinsic susceptibility index (GwISI) and (ii) aquifer vulnerability index (AVI).

The five (5) steps of the Groundwater Vulnerability Analysis (NPCA, 2009a) completed to delineate the HVAs consisted of:

Step 1: Review and assess available data and interpretations – Section 4.1.1
Step 2: Assess Vulnerability – Section 4.1.2
Step 3: Consider vulnerability Increase for Transport Pathways – Section 4.1.3
Step 4: Assign Vulnerability Scores – Section 4.1.4
Step 5: Evaluate Uncertainty – Section 4.1.5

4.1.1 Review and Assess Available Data and Interpretations

Regional-scale NPSP Area groundwater vulnerability maps were reviewed for their suitability in the vulnerability assessment. From this review it was determined that the NPCA Groundwater Study (WHI, 2005) mapping was the most suitable because:

1) It was produced using groundwater vulnerability assessment methods that are approved in the TR; and
2) It was the only map product which was seamless across the NPSP Area.

The groundwater vulnerability was assessed using GwISI and AVI methods, TR 37 (1) and 37 (2), respectively. The GwISI analysis was completed for the entire study area using MOE WWIS. The AVI analysis was only completed with respect to (i) surficial overburden and (ii) bedrock at surface aquifers, e.g. the Fonthill Kame-Delta Complex and Niagara and Onondaga Escarpments, respectively.

The final NPCA Groundwater Study vulnerability map was a conservative combination of the two methods. The GwISI results were similar to other consultants' adjacent maps in the City of Hamilton and Haldimand County where the MOE WWIS was the principal dataset.

4.1.2 Assess Vulnerability

4.1.2.1 Intrinsic Susceptibility Index (GwISI)

As mentioned above, the GwISI map (Figure 4.1) was obtained from the NPCA Groundwater Study (WHI, 2005). The GwISI map is considered to reflect the vulnerability either to the water table aquifer or to the first confined aquifer layer. The vulnerability was based upon the following matrix:

GwISI/AVI Score	Vulnerability
<30	High
30-80	Medium
>80	Low

Review of the GwISI against available regional hydrostratigraphic interpretations suggests that the distribution of high vulnerability is under-estimated in some areas. This is a limitation of digital contouring to map linear features, e.g. the Niagara Escarpment. It is also a limitation of the distribution of the MOE WWIS dataset, both vertically, where there are multiple aquifers, and horizontally, between available well records. Despite these limitations the GwISI was considered a good basis for the vulnerability assessment but needing the improvement of some additional AVI mapping.

4.1.2.2 Aquifer Vulnerability Index (AVI)

AVI groundwater vulnerability assessments were also completed to improve the delineation of HVAs. The specific aquifers (for background see Section 3.6.1) considered were:

I. surficial water table aquifers (both overburden and bedrock); and
II. unconfined/semi-confined bedrock aquifers (i.e. having less than 5 metres of overburden).

The AVI groundwater vulnerability assessments were based on regional hydrostratigraphic interpretations (Section 3.6) and hydraulic conductivity assignments (or K-Factor) based on the aquifer/aquitard designation and the overburden thickness (Figure 3.12). For example, the AVI score for unconfined/semi-confined bedrock aquifers was based upon a maximum thickness of 5 m of weathered clay (Section 3.6.2) and a K-Factor of 3 (Table 3.1, MOE, 2006b). Multiplying 5 by 3 produces a score of 15, and a designation of high vulnerability. It should be noted that clay deeper than 5 m is not considered weathered enough to have a K-Factor of 3 or more.

The AVI for the surficial water table aquifers correspond with High. The AVI for the semi-confined bedrock aquifers also correspond with High. The extent of the AVI vulnerability assessments for HVAs are shown on Figure 4.2.

4.1.2.3 Combined Groundwater Vulnerability

The combined GwISI and AVI vulnerability assessments are presented on Figure 4.3 and tabulated in Table 4.1.

Table 4.1 GwISI/AVI Vulnerability Results						
	High		**Medium**		**Low**	
Boundary (size km^2)	**km^2**	**%**	**km^2**	**%**	**km^2**	**%**
NPCA (2,409)	616	26%	740	31%	1,053	44%
Niagara Region (1,871)	541	29%	555	29%	776	41%
City of Hamilton (237)	29	12%	107	45%	101	42%
Haldimand County (302)	47	16%	79	26%	176	58%

Note: some disagreement between sum areas and individual values is caused by rounding of significant digits

The results of the mapping indicate the following as modified from the NPCA Groundwater Study (WHI, 2005):

Areas of low susceptibility occur mainly in the central portions of the NPSP Area, and correspond to thick deposits of clay and silt of the Haldimand Clay Plain. This material, below 5 m BGS, restricts the downward movement of infiltrating surface water, making the underlying groundwater much less susceptible to associated contamination.

Areas of high susceptibility:
1. *Occur mainly in the presence of high permeability overburden units with little, or no, low conductivity layers overlying the aquifer. These include the Fonthill Kame-Delta Complex, the Iroquois Sand Plain, and the Dunnville Sand Plain.*
2. *Occur where the bedrock outcrops or is overlain by thin (i.e. <5 m) deposits.*

4.1.3 Vulnerability Increase for Transport Pathways

The transport pathways that were considered to have potential to increase groundwater vulnerability are (Figures 4.4, 4.6, 4.7 and 4.8):
- Private water wells (including unused wells needing decommissioning)
- “Unknown” status oil and gas wells
- Aggregate operations; and
- Construction activities along the Welland Canal.

Other transport pathways, such as septic systems, storm water facilities and sanitary sewers, were not included as they are not likely to increase this regional groundwater vulnerability mapping.

4.1.3.1 Existing Wells

Private wells are considered to have the potential to increase groundwater vulnerability as transport pathways. Well clusters are identified as priority risks because of the high-density of wells connected to the underlying aquifer. Well clusters were defined as being six wells located within 100 m radius of each other (Jagger Hims Limited, 2009). This analysis was completed using MOE WWIS and Ministry of Natural Resources (MNR) oil and gas well records, but not including officially abandoned records. There were 750 wells identified in this analysis (only one was from the MNR dataset). The groundwater vulnerability has been raised to high for a 30 m radius around each individual well identified to be part of a cluster. A 30 m radius was chosen based on the recommended setback distance from contamination sources in Ontario Regulation 903 (Wells Regulation) as amended (this distance has also been incorporated in the Ontario Building Code).

Wells older than 10 years (pre-2000) were also considered transport pathways to potentially increase groundwater vulnerability. This is because newer wells are likely to be constructed to a higher standard and therefore are a lower risk. The groundwater vulnerability has been raised to high for a 30 m radius around each of these 8,548 wells identified as older than 10 years.

In each of these cases the vulnerability was increased to high from either medium or low. This is because by their very nature these wells are constructed as a pathway from the surface to the aquifer through the naturally protective layers that may be present. To put this in context of the NPSP Area, as described in Section 3.6.1, there is generally only one local, drilled well, aquifer unit, in a given locality of the NPSP Area. This aquifer may be: (i) the contact-zone aquifer overlying the uppermost bedrock aquifer, (ii) a surficial overburden aquifer overlying the uppermost bedrock aquifer or (iii) a bedrock aquifer at, or very close to, surface. Consequently, specific existing wells situations, as described above, have the potential to be transport pathways to the local aquifer.

4.1.3.2 Unused Wells

There are 1,479 MOE WWIS records of former "water supply" wells in areas now serviced by municipal water. These transport pathways also present a high risk to the underlying aquifers. The groundwater vulnerability has been raised to 'high' for parcels containing an unused well and a 30 m radius around each of the 332 wells that were not located on parcels.

4.1.3.3 Oil and Gas Wells

There are also oil and gas wells completed in the NPSP Area. Since the early 1990s, license requirements govern use and abandonment through the Ministry of Natural Resources (MNR). However the status of abandonment of some oil and gas wells prior to the 1990s is unknown. These earlier installations may not have been properly abandoned or plugged, i.e. they may not be sealed and if sealed, may not have been sealed in a method that will minimize the vulnerability of the shallow groundwater systems.

Potentially un-plugged wells, status being "unknown" and generally pre-dating 1992, have been included as transport pathways. The groundwater vulnerability has been raised to 'high' for a 30 m radius as they pass through the water supply aquifers. There are 1,633 unknown status wells in NPSP Area.

4.1.3.4 Aggregate Operations

Aggregate operations, i.e. pits and quarries, are transport pathways because they reduce the amount of overlying material to filter and/or attenuate contaminants. In the NPSP Area there are 31 authorized aggregate sites, and 103 historic pit and quarry locations. The vulnerability category for historic and licensed pits and quarries were raised to high as there is no protection to the aquifer. These locations are already generally classed as highly vulnerable (Table 4.2) because they are often sited where the resource is close to surface and correspond with overburden or bedrock aquifers.

Table 4.2 Aggregate Resources Vulnerability			
GwISI/AVI Vulnerability	Transport Pathway Vulnerability	Area (km^2)	Percent (%)
High	High	20.3	55
Medium	High	15.8	43
Low	High	0.6	2

4.1.3.5 Construction Activities along the Welland Canal

Construction activities can alter the natural environment through the removal of low permeability units. An example of this is the Welland Canal. Two sections of the Canal's channel bed sit directly on bedrock and can act as a source of recharge to the groundwater system (Frind, 1970), e.g. the contact zone aquifer. The St. Lawrence Seaway Management Corporation has confirmed that the two sections for which the canal bottom is cut into bedrock are from (i) Glendale Avenue, St. Catharines to Hurricane Road, Thorold, and from (ii) Ramey's Bend, south of Dain City southward to Lake Erie (Fraser Johnston, personal communication 2009). The susceptibility categories underlying these areas will be raised to high as there is no protection to the aquifer.

4.1.3.6 Transport Pathways Summary

In accordance with TR 39, 40 and 41, medium and low groundwater vulnerabilities were modified to high if preferential pathways were present. This was based on consideration that the presence of transport pathways have the high potential to, or actually remove, natural groundwater protection from water supply aquifers (Figure 4.5).

The overall increase in HVAs from the consideration of transport pathways is 46 km^2 or about 2% of the NPSP Area. Table 4.3 updates Table 4.1 to include this additional area. Most of this increase is mapped in Niagara Region and the City of Hamilton.

Table 4.3 GwISI/AVI/Transport Pathway Vulnerability Results						
	High		**Medium**		**Low**	
Boundary (size km^2)	**km^2**	**%**	**km^2**	**%**	**km^2**	**%**
NPCA (2,409)	662	27	711	30	1,036	43
Niagara Region (1,871)	557	30	544	29	77	41
City of Hamilton (237)	57	24	89	38	91	39
Haldimand County (302)	48	16	78	26	175	58

Note: some disagreement between sum areas and individual values is caused by rounding of significant digits

4.1.4 Assign Vulnerability Scores

HVAs, i.e. areas of high groundwater vulnerability, were delineated for the NPSP Area based on the previously discussed analyses and are illustrated on Figure 4.9. The HVAs delineation reflects the increased vulnerability of the shallowest identified aquifers by transport pathways. As per TR 79, HVAs are assigned a vulnerability score of 6.

4.1.5 Evaluate Uncertainty

The overall confidence in the Vulnerability Assessment as per Table 4.4 is 7 out of a possible 10. A value greater than 6 is assumed to reflect sufficient confidence that the results can be relied on for the purpose of the Vulnerability Analysis. The Uncertainty Score recommended for the NPSP Area Vulnerability Assessment based on Table 4.4 is Low. This uncertainty score reflects the combination of the confidence scoring assigned from the assessment of the quantity, quality and distribution of the available data. The uncertainty scoring suggests a high level of comfort in how representative the generated vulnerability scoring is for the NPSP area and how well it corresponds to the available data and previous work completed by others in the area.

The delineation of the GwISI contact-zone aquifer vulnerability is largely a function of the MOE water well records, not the actual stratigraphy. Consequently, some higher vulnerability areas where wells are not completed, may not have been mapped. Also the contouring procedure is of the well data, not the aquifer, and may not have "connected" higher vulnerability zones because of limitations of this automated process.

Both the exact location, and the status, of wells (water, oil and gas) considered to be transport pathways are unknown. However by their inclusion in the transport pathways assessment it is a conservative approach to address their potential to contaminate the aquifers.

As part of the uncertainty analysis, a peer review of the draft groundwater vulnerability report was completed by Jagger Hims Limited (a division of GENIVAR), and Terra-Dynamics Limited. The HVAs report was revised accepting the recommendations of the peer reviewers.

TR 9(2), 13, and 14
TR 43, 5(2), 37, 38, 38.1, 38.2, 9(1)(c)(1)

TABLE 4.4: QUALIFICATION OF UNCERTAINTY

Part 1. Assessment of Available Data

Confidence Score (x/10)	Aquifer(s) Considered:	Water Table/ Uppermost Aquifer	Target Aquifer	Other Aquifers
7	**Qualitative Assessment of Conceptual Understanding:**			
	Is the Groundwater Flow System Simple, Uniform?	Y	Yes at a regional scale assessment level	
	Does Groundwater Flow reflect topography & regional watershed drainage?	Y		
	Are there other reasonable interpretations of Groundwater Flow System?	N		
	Are watershed/surface water interactions satisfactorily represented?	Y		
	Is the Aquifer Confined?	Y		
	Is the Target Aquifer in a complex Groundwater Flow System?	Y	Predominantly	
	Is the Target Aquifer in fractured rock?	N	Yes but regional scale assessment equivalent porous media approach acceptable	

Part 2. Assessment of Vulnerability Assessment

	Vulnerability Method (Evaluate one method Only):	Basic Hydrogeological Evaluation	Intrinsic Susceptibility Index (ISI)	Aquifer Vulnerability Index (AVI)	WAAT/ SAAT/ SWAT	Detailed Hydrogeological Evaluation	Progressive Evaluation (more than one approach)
7.5			X	X			Y
	Based on/Considers Regional Stratigraphic Interpretations:						Y
	Based on/Considers Local (Individual Borehole) Interpretations:						N
	Does Vulnerability Assessment reasonably reflect data?						Y
	Is Vulnerability Assessment Consistent with Regional Understanding?						Y

Part 3. Uncertainty Assessment

7.0	Assessment of Available Data/Interpretation
7.5	Assessment of Vulnerability
LOW	**RECOMMENDED UNCERTAINTY SCORE**

4.2 Significant Groundwater Recharge Areas (SGRAs)

SGRAs are one of the four vulnerable areas outlined in the *Clean Water Act*, *2006*, requiring delineation and protection. The Act defines a 'significant groundwater recharge area' as an area within which it is desirable to regulate or monitor drinking water threats that may affect the recharge of an aquifer (O. Reg. 287/07 Section 1(1)). Recharge areas are classified as "significant" when they supply more water to an aquifer used as a drinking water source than the surrounding area. Once SGRAs are delineated, they are further subdivided by areas of groundwater vulnerability.

4.2.1 Methodology

According to the TR (MOE, 2009), an area is a SGRA if,

"the area annually recharges water to the underlying aquifer at a rate that is greater than the rate of recharge across the whole of the related groundwater recharge area by a factor of 1.15 or more" TR44 (1); or

"the area annually recharges a volume of water to the underlying aquifer that is 55% or more of the volume determined by subtracting the annual evapotranspiration for the whole of the related groundwater recharge area from the annual precipitation for the whole of the related groundwater recharge area" TR44(2).

Despite these criteria, an area shall not be delineated as an SGRA unless the area has a hydrological connection to a surface water body or aquifer that is a source of drinking water for a drinking water system (TR 45). Also the SGRA delineations are to be completed using the water budget models (Chapter 3) that include the effects of topography, soils, surficial geology, and land cover on recharge (TR 46).

4.2.2 Groundwater Recharge

Recharge occurs where there is downward movement of water from the ground surface towards the water table. The rate at which recharge occurs is dependent on such factors as slope, soil type, land-use, and climate. For example, hilly terrain with a clay soil type and covered by urban lawns will result in a lower infiltration rate compared to a mature forest overlaying sandy loam on a flat area. This is because higher slopes and clayey soils increase runoff, reducing the amount of water available to infiltrate.

Estimates for recharge were determined in the Tier 1 Water Budget – Water Availability Studies (AquaResources Inc. and NPCA, 2009) for the NPSP Area through HEC-HMS continuous surface water modelling. Catchment recharge results were then distributed using the MOE/MNR recommended approach of infiltration factors (Figure 4.10). Infiltration factors are a function of topography, land cover, and soil texture (MOE, 1995). A small percentage of land could not be modelled and so these areas were assigned recharge values which had similar topography, land cover, and soils by a "pro-rating" procedure.

4.2.3 SGRA Delineation

SGRAs were identified where groundwater is recharged by a factor of 1.15 or more of the average recharge rate. This method (TR 44(1)) is recommended in technical guidance (MNR and MOE, 2009) where recharge rates are fairly homogenous and is meant to distinguish between high and low recharge. Homogenous clay-like recharge rates dominate the NPSP Area whereby 95% of the values, or two standard deviations of the average value, are less than or equal to 100 mm/year (the standard deviation was 27 mm/year).

The average recharge rate for the NPSP Area is 46 mm/year. This is a very low recharge rate, and is due to the high clay content in the soils across the NPSP Area. The TR 44(1) criterion for NPSP Area SGRAs is then 53 mm/year. The SGRAs are significant because they account for 40% of the recharge while covering only 22% (542 km^2) of the NPSP Area (Figure 4.11).

The area around the Fonthill Kame-Delta Complex has a groundwater recharge of greater than 150 mm/year, which is comparatively high for this source protection area (Figure 4.10). Areas of recharge greater than 40% of the water surplus (precipitation minus evapotranspiration) are almost entirely limited to this area.

As a result of the extensive private water system aquifer coverage and recharge providing over half of the overall groundwater supply (Section 3.6) these SGRAs are believed sufficiently hydrologically connected to the laterally extensive aquifers described in Section 3.6.1 to meet the criterion of TR 45. However areas that were adjacent a Great Lakes shoreline and serviced by municipal water were removed (and amounted to about 6 km^2).

TR 46

4.2.4 Vulnerability Scores for SGRAs

SGRAs cover 542 km^2 or about 22% of the NPSP Area based upon a criterion of 53 mm/year or greater (Figure 4.12). About half of the SGRAs are also mapped as highly vulnerable in the NPSP Area (Table 4.1). Table 4.5 summarizes the distribution of SGRA's throughout the NPSP Area.

Table 4.5 SGRA Groundwater Vulnerability Distribution

Boundary (size km^2)	SGRA size km^2 (% of Area)	High km^2 (%)	Medium km^2 (%)	Low km^2 (%)
NPCA (2,409)	542 (22%)	270 (50%)	129 (24%)	144 (27%)
Niagara Region (1,871)	420 (22%)	230 (55%)	102 (24%)	89 (21%)
City of Hamilton (237)	82 (35%)	18 (22%)	21 (26%)	43 (53%)
Haldimand County (302)	40 (13%)	22 (55%)	6 (15%)	12 (30%)

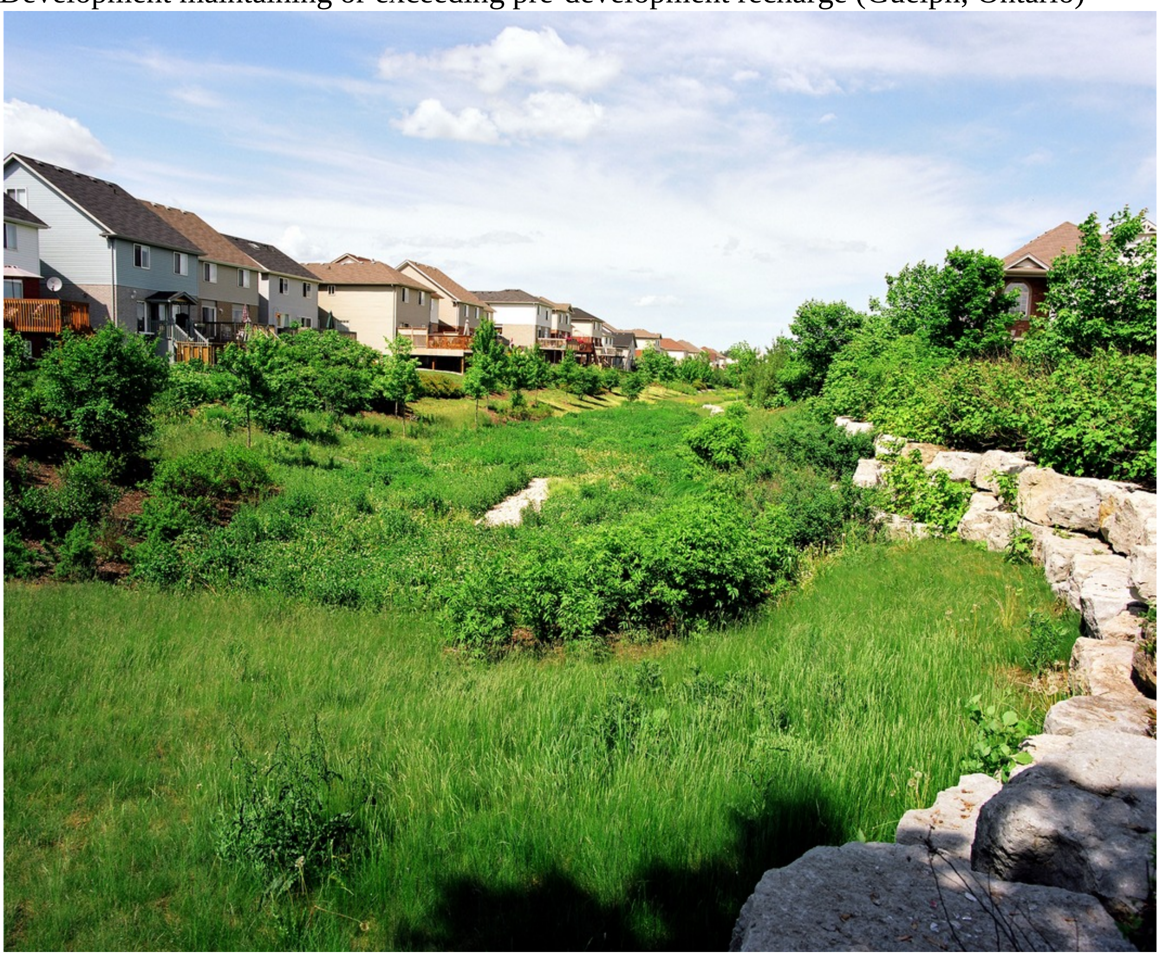
Note: some disagreement between sum areas and individual values is caused by rounding of significant digits

SGRAs are subdivided by the groundwater vulnerability and assigned scores of 6, 4 or 2 for groundwater vulnerabilities of high, medium and low, respectively. This is according to TR 80 and 81 (Table 4.6).

Table 4.6 SGRAs Vulnerability Scores	
Groundwater Vulnerability	Vulnerability Score
High	6
Medium	4
Low	2

TR 79, 80, 81

Development maintaining or exceeding pre-development recharge (Guelph, Ontario)



4.3 Identification of Threats

4.3.1 Prescribed Threats

Drinking water threats for vulnerable areas are prescribed by the province in paragraphs 1 through 18 and paragraph 21 of subsection 1.1(1) of O.Reg. 287/07. These drinking water threat categories are also listed and described in Section 5.4.1 of this report. The drinking water threat categories are further divided into 1,920 Threat Circumstances that are described in the MOE's Table of Drinking Water Threats (TDWT). The TDWT determines if a given activity/circumstance is a low, moderate, or significant drinking water threat, depending on the vulnerability score of the vulnerable area it is located in.

HVAs and highly vulnerable SGRAs cannot have significant threats by virtue of their vulnerability scores of 6. Appendix C contains the MOE's *Provincial Tables of Circumstances 10, 17 and 18* for moderate and low chemical circumstance threats for HVAs and SGRAs with vulnerability scores of 6. There are no pathogen threats listed however by the MOE for HVAs or SGRAs (Table 4.7). Figure 4.9 illustrates where activities in HVAs and highly vulnerable SGRAs would be moderate, or low drinking water quality threats based on a vulnerability score of 6.

Figure 4.9 should be viewed in conjunction with Table 4.7 and Appendix C to determine specific activities within an HVA/SGRAs (with a vulnerability score of 6) that would be significant, moderate, or low drinking water quality threats.

Table 4.7 : References for Provincial Tables of Circumstances

SGRA & HVA	Vulnerability Score	Provincial Table Reference - Chemical Threats			Provincial Table Reference - Pathogen Threats		
		Sig.	Mod.	Low	Sig.	Mod.	Low
SGRA & HVA	6.0	- -	Appendix C.31 and C.33	Appendix C.32	- -	- -	- -

There are eight (8) moderate chemical drinking water threats possible in the Table of Drinking Water Threats (as shown on Table 4.8).

The potential chemical drinking water threats only concern vinyl chloride or other dense-non-aqueous-phase-liquids (DNAPL) that could degrade to vinyl chloride. Examples of DNAPLs that could degrade to vinyl chloride include the chlorinated solvents: tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-Dichloroethylene (1,1-DCE), cis-1,2-Dichloroethylene, trans-1,2-Dichloroethylene (tr-1,2-DCE) and 1,1,1-trichloroethane (1,1,1-TCA).

Table 4.8 - Vinyl Chloride Moderate Chemical Groundwater Threats				
TDWT Ref#	**Prescribed DWT**	**Threat Subcategory**	**Chemical Quantity Circumstance**	**Chemical Circumstance**
1083 1096	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.	Sewage System Or Sewage Works - Storage Of Sewage (e.g. Treatment Plant Tanks)	Sewage Treatment Plants that discharge treated effluent >=50,000 m3/d on an annual average	STP holding tank that is installed completely or partially below grade, except for the access points
1674 1710	The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the Environmental Protection Act.	Waste Disposal Site - Landfilling (Municipal Waste or Solid Non Hazardous Industrial or Commercial)	Landfill area > 10 ha	Land disposal of municipal waste, or solid non hazardous industrial or commercial
1877		Waste Disposal Site - Liquid Industrial Waste Injection into a well	Throughput rate of >38,000,000 cubic metres per year.	Land disposal of liquid industrial waste by discharging into a geological formation by means of a well
106	The handling and the storage of a DNAPL	Handling Of A Dense Non Aqueous Phase Liquid (DNAPL)	Any quantity	The below grade handling of a DNAPL in relation to its storage
1107 1112		Storage Of A Dense Non Aqueous Phase Liquid (DNAPL)		The storage of a DNAPL completely or partially below grade

Table Notes: TDWT is the MOE's Table of *Prescribed* Drinking Water Threats. For more information see *Section 5.4.1 Prescribed Activities*.

TR 118.1

4.3.2 Enumeration/Listing of Existing Threats

The TR require the enumeration or listing of locations at which:

- A person is engaging in an activity that is or would be a significant threat; and
- A condition resulting from a past activity is a significant drinking water threat.

As noted earlier in Section 4.3, there are no significant drinking water threats in the HVAs/SGRAs since these vulnerable area have a maximum vulnerability score of 6 in the NPSPA. However, existing moderate groundwater threats have been enumerated, using available datasets reviewed in a geographic information system (GIS), as these threats may be addressed in the Source Protection Plan. The enumerated existing moderate threats in HVAs/SGRAs are outlined below.

4.3.2.1 TDWT 1083 and 1096 – Sewage Systems/Works

No sewage systems or sewage works were identified as moderate groundwater threats. There are sewage treatment plants on HVAs, however none discharge greater than or equal to 50,000 m^3/day, (which is the criterion to be a moderate threat).

4.3.2.2 TDWT 1674 and 1710 – Waste Disposal Sites

Waste disposal sites (1674 and 1710) were determined to be potential moderate threats using a number of available datasets (Table 4.9). For consideration as a moderate groundwater threat for HVAs and SGRAs with a vulnerability score of 6, the Table of Drinking Water Threats criterion is that the landfill area be greater than 10 hectares (or 100,000 m^2). However, most locations given did not include the area of the waste disposal sites (gathering that information could be part of a future phase of work). Therefore the analysis is highly conservative and most sites identified are expected to be less than 10 ha. One hundred and five (105) waste disposal sites were identified in the NPSP Area and forty-six (46) were located on HVAs and greater than 10 ha or had to be assumed as such. Seven (7) waste disposal sites were located on SGRAs with a score of 6. However only nine (9) sites are active in HVAs and no sites are active on SGRAs with a score of 6.

Table 4.9 Waste Disposal Site Datasets

Dataset	Categories Listed	Data Type	Date
Niagara Water Quality Protection Strategy	Industrial landfill sites Old dump fill sites Closed landfill sites Operating Landfill sites	Point file	2003
Waterloo Hydrogeologic Inc.	Active landfills Closed landfills	Point file	2005
Niagara Region Waste Management	Closed landfill sites Open landfill sites	Polygon file	2009

Note: Point files did not contain area of site

The Ministry of the Environment Environmental Assessment and Approvals Branch has indicated there are no deep well injections of liquid industrial waste (1877) in the NPSP Area.

4.3.2.3 TDWT 106, 1107 and 1112 Handling and Storage of DNAPLs etc

The handling and storage of vinyl chloride, and DNAPLs that could degrade to vinyl chloride, was considered using the Hazardous Waste Information Network (HWIN) database (MOE, 2007). The HWIN database was queried to locate waste class "212" (aliphatic solvents and residues), which includes vinyl chloride, and DNAPLs that could degrade to vinyl chloride. Fifty-nine (59) generators were located in the NPSP Area and fifteen (15) were located on HVAs. Two (2) were located in SGRAs with a vulnerability score of 6. The Technical Standards and Safety Authority database of storage tanks was not used because it is limited to fuels.

4.3.2.4 Table of Enumerate Threats

The enumeration of NPSP Area potential moderate groundwater threats are presented in Table 4.10.

Table 4.10 – Moderate Chemical Groundwater Threat Enumeration		
Prescribed DWT	**HVAs**	**SGRAs**
The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.	0	0
The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the Environmental Protection Act.	9	0
The handling and the storage of a DNAPL	15	2
TOTAL	24	2

4.3.2.5 Conditions

According to the TR and MOE's Tables of Drinking Water Threats shown in Appendix C, there can be no prescribed significant threats and therefore there are no conditions were enumerated that would represent a significant threat. An enumeration of groundwater conditions for HVAs and SGRAs was not completed but would be a valuable future task and is considered a data gap for these potentially moderate threats.

TR 132

4.4 Evaluation of Drinking Water Issues

4.4.1 Wainfleet Lakeshore Area

Nitrate is a documented issue for private groundwater systems in the Wainfleet Lakeshore Area (as introduced Section 2.4.2). These private wells are not listed as a system, or systems, in the Terms of Reference. Nitrate has a maximum acceptable criterion (MAC) for health protection of 10 mg/L as listed under Schedule 2 of the Ontario Drinking Water Quality Standards (MOE, 2006).

In 2002, MacViro Consultants Inc. (working on behalf of Niagara Region) determined that, in addition to widespread groundwater microbial contamination (30% MAC e.coli and 52% total coliform exceedances) , that nitrate concentrations in private well systems exceeded the MAC in 10 of the 128 homes tested or 8% (maximum concentration of 44 mg/L). Elevated nitrate concentrations also indicated negative human impacts in another 43 of the wells tested or 34%, as shown by nitrate concentrations ranging from 4-10 mg/L in 22 of the wells and 1-4 mg/L in another 21 of the wells tested. Of the homes tested only 11% or 14 had treatment systems capable of removing nitrate. Nitrate is thereby an issues as per rule TR 114.

The 2002 study informed the provincially approved Wainfleet Water and Wastewater Servicing Plan Class Environmental Assessment Environmental Study Report (ESR) (EarthTech, 2005): *"The results of the study* (noted above) *determined that the majority of wells assessed along the lakeshore have water quality problems associated with sewage contamination, as shown by the exceedances in E.Coli, total coliform and nitrates. Elevated levels of ammonia, phosphate and chlorides, indicators of sewage effluent and development impacts, were also found."* The report also identified the "widespread" area of concern based upon work completed by AMEC and the Niagara Region Health Department (On-site sewage system sustainability report, 2005). The area of concern was largely determined based upon identified failing septic systems, high use of sewage holding tanks and small lot sizes. This area of concern is the "issue contributing area" (TR 115 (3)) (Figure 4.13).

In 2006, following additional water quality testing in 2005, MacViro Consultants Inc. identified a greater total number of wells with nitrate concentrations exceeding the MAC in the Wainfleet Lakeshore Area, a total of 18 versus the 10 in 2002. The health related MAC for fluoride was also exceeded in wells at Morgan's Point and Camelot beach but this is likely naturally occurring.

The provincial table of circumstances for low chemical threats in a highly vulnerable aquifer (Appendix C.32, Table18) lists different categories of activities that can cause nitrate contamination, these include:

- Application of agricultural source material, fertilizer, non-agricultural source material or untreated septage to land;
- Storage of agricultural source material, fertilizer, non-agricultural source material, sewage or snow;
- Grazing, pasturing, and animal confinement yards;
- Sanitary sewers and sewage treatment plant effluent discharges;
- Septic systems and holding tanks;
- Discharge of untreated stormwater;
- Waste disposal sites; and
- Storage, treatment and discharge of tailings from mines.

However the 2005 ESR study has indicated that "*private residential septic systems adversely affect groundwater supplies*" and that "*the failure and malfunctioning of the existing private septic tank systems in the Lakeshore Communities in some cases include raw sewage in roadside ditches, odours associated with these sewage discharges and on-site ponding from tile field breakouts*". The ESR study identified septic systems and sewage holding tanks (threat circumstances 698 and 710, Appendix C, Table 18) as the drinking water threats contributing to the parameter of concern, nitrate (TR 115 (4), 118).

In summary, septic systems and sewage holding tanks are moderate drinking water threats because nitrate concentrations are above provincial health criteria in a widespread area of private water wells (Figure 4.13) in the Wainfleet Lakeshore Area (TR 114(3)(a)) as a consequence of aging and failing septic systems (TR 115) as reported on in a provincially approved EA.

4.5 Wellhead Protection Area Delineation

Wellhead protection areas (WHPAs) encompass the land area that provides recharge to a well, or well field. There are a number of different methods that can be used to delineate a WHPA. These methods range from simply delineating an area by establishing an arbitrary distance from the wellhead, to more complex methods that use numerical groundwater flow and particle tracking computer models.

There are no municipal WHPAs in the NPSP Area, since there are no municipal wells currently in operation. However, there is a possibility that a hamlet containing several private wells in close proximity could be designated as a WHPA in the future, through a resolution of one of the local municipal councils. At this time no hamlets have been designated in the NPSP Area.

4.6 Technical Advisory Groups and Peer Review

The Technical Advisory Group for delineation of the highly vulnerable aquifers consisted of staff from NPCA. Peer review of the HVA delineation was completed by GENIVAR (formerly Jagger Hims Limited) and Terra-Dynamics Limited. The HVAs report was revised accepting the recommendations of the peer reviewers. The HVAs report was accepted and endorsed by the peer review team.